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(54) Dual polarised phased array antenna.

(57) A dual polarised phased array antenna is formed by intersecting two parallel sets of circuit boards (11,12) respectively carrying orthogonally polarised antenna elements (17). In prior antennas corresponding orthogonal elements mutually coincided with board intersections and interengagement slots restricted on-board circuit interconnection of elements.

In the improvement the elements (17) are spaced from the board intersection slots (14) facilitating circuit interconnection along the board. Also the phase centres (16) of those antenna elements (17) relating to one polarisation direction are offset from the phase centres of corresponding antenna elements relating to the other polarisation direction. An array employing Vivaldi slot antenna elements is described

Fig.2.

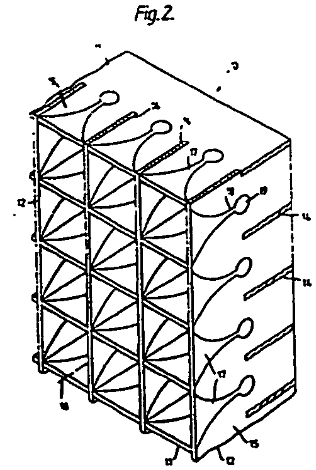

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Fig.3a.

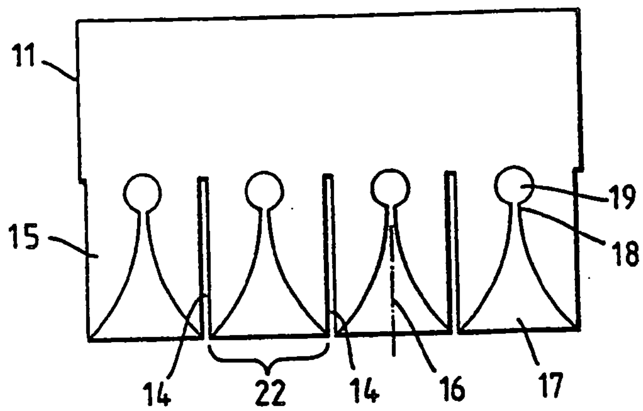
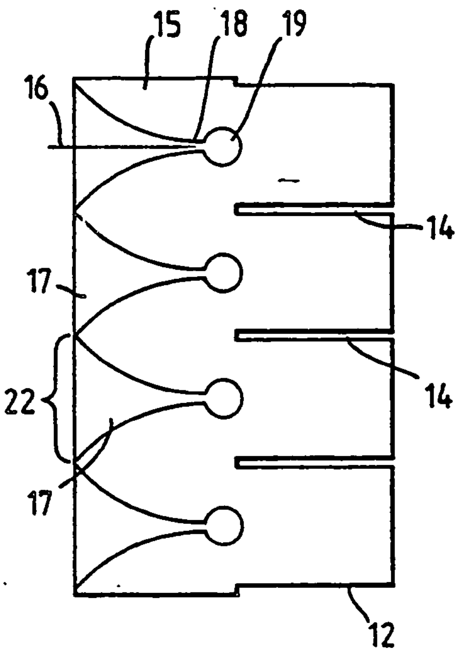


Fig.3b.



DUAL POLARISED PHASED ARRAY ANTENNA

The invention relates to a dual polarised phased array antenna comprising two corresponding matrix arrays of antenna elements respectively providing orthogonal directions of polarisation, mounted on a support structure and energised by associated feeder means so as to form a phased antenna array of corresponding polarisation, said support structure comprising an assembly of two orthogonal sets of parallel insulating planar supports, the supports of one set intersecting and interengaging the supports of the other set to form a support structure of matrix form, the insulating planar supports of each set each being provided with a conductive surface pattern including a succession of said antenna elements distributed along a corresponding outward facing edge of the planar support. The respective orthogonal directions of polarisation are normally vertical and horizontal. Dual polarised phased array antennas of the kind specified can be employed in radar and other direction finding systems, and conventionally have the phase centres of their corresponding vertical and horizontal polarisation elements coincident with one another.

Such a dual polarised phased array antenna of the kind specified has been disclosed by L.R. Lewis, m. Fassett and J. Hunt, in a note entitled "A broadband stripline array element", published in the IEEE/AP-S Symposium Program and Digest June 1974, Atlanta, Georgia, pages 335 to 337, which describes an antenna array the antenna elements of which comprise tapered notches. Figure 1 a of the accompanying drawings illustrates the form of dual polarised array therein disclosed and Figures 1b and 1c respectively illustrate details of the vertical and horizontal insulated planar supports and the slots formed therein for the purpose of intersection and interengagement.

Figure 1a shows a portion of the known dual polarised phased array antenna 1 described in the above reference which is said to be a square steerable array consisting of 256 (16x16) antenna elements 2. The support structure 3 of the antenna array 1 comprises an assembly of two orthogonal sets of parallel insulating planar supports 4,5, the supports of one set intersecting and interengaging the supports of the other set by means of corresponding co-acting slots 6, to form a support structure of matrix form. The horizontal and vertical supports 4,5, are each provided on both faces with a conductive surface in the form for example of copper cladding and a succession of antenna elements in the form of tapered notches are formed, for example by etching, so that they are distributed along a corresponding outward facing edge of the planar support 4,5, when assembled to form the matrix structure 3. In conventional manner, the phase centres of the horizontally polarised antenna elements 2 on the parallel horizontal planar supports 4, are arranged to coincide with the phase centres of the corresponding vertically polarised antenna elements 2 on the parallel vertical planar supports 5. This requires that the centre of each antenna element 2 must correspond to the centreline of a corresponding slot 6 in the respective planar support 4,5.

The tapered notch antenna arrays 2 are each fed by a triplate stripline feed 8 embedded in the dielectric forming the corresponding planar support, which traverses the slot and is effectively grounded to the surface conductor by an open circuit half wavelength extension on the far side. It will be apparent from Figures 1b and 1c that the feeder coupling point for elements on the horizontal supports will be different in location and therefore in electrical characteristics than that for elements on the other support which means that, in general one of the arrays will not be operating under optimal conditions. One advantage of forming a dual polarised phased array antenna using a structure of interlocking planar supports which can for example comprise printed circuit boards employing a suitable dielectric such as glass fibre reinforced polytetrafluorethelene (PTFE) or a polyolefin, is ease and economy of manufacture. However a significant further advantage of using circuit boards in a phased array would be the case of mounting amplifying, receiving and phase changing circuitry on each board to control the passage of signals to and from the respective antenna elements carried on the board. However in the case of one set of boards, as will be apparent from Figure 1c, the coincidence of the antenna elements 2 with the corresponding slot 6 will make it impossible to use the conductive cladding to carry interconnections along the boards from one antenna element to another and such interconnections would therefore have to be made external to the board adding to the expense of manufacture.

It is an object of the invention to provide an improved dual polarised phased array antenna which can be less costly to manufacture.

According to the present invention there is provided a dual polarised phased array antenna comprising two corresponding matrix arrays of antenna elements respectively providing orthogonal directions of polarisation, mounted on a support structure and energised by associated feeder means so as to form a phased antenna array of corresponding polarisation,said support structure

comprising an assembly of two orthogonal sets of parallel insulating planar supports, the supports of one set intersecting and interengaging the supports of the other set to form a support structure of matrix form, the insulating planar supports of each set each being provided with a conductive surface pattern including a succession of said antenna elements distributing along a corresponding outward facing edge of the planar support, characterised in that the phase centres of those antenna elements forming the matrix array relating to one polarisation direction, are offset from the phase centres of corresponding antenna elements forming the other matrix array.

If desired the respective phase centres of each of the antenna elements may be located on the corresponding planar support between successive intersections therewith of planar supports orthogonal thereto.

The antenna elements formed by the conductive surface pattern on the insulating planar supports, may each comprise a tapered slot antenna element formed by the conductive surface pattern on the associated insulating planar support. The tapered slot may comprise an exponential taper. It is however possible to employ other suitable printed circuit antenna elements such as a simple dipole or a Yagi array.

The insulating planar supports may be moulded from a suitable dielectric material or they may be formed from sheet dielectric material by stamping, cutting or milling. The dielectric may be a suitable plastics material such as a polyolefin or preferably a glass fibre reinforced PTFE and the conductive surface pattern may be formed, for example, from copper cladding on the insulating planar supports by means of any suitable printed circuit technique. Alternatively, the insulating planar supports may be formed of alumina or quartz and the conductive surface pattern may be formed on the surface thereof by a thick film process or by vapour deposition, for example via a mask, of a suitable metallisation system, for example nichrome-gold.

The dual polarised phased array antenna in accordance with the invention can be assembled relatively inexpensively from an assembly of component linear sub-arrays. The form of assembly ensures that the sub-arrays are located and maintained at the correct spacing from one another. The sub-arrays can be assembled and tested before inclusion in the assembled array, and the sub-arrays can be included or replaced in the complete array without introducing or removing any additional microwave wiring.

Where reference is made herein, explicitly or implicitly, to radiation of electromagnetic energy by an antenna, it should be understood to apply equally to the reception of electromagnetic energy thereby, since an antenna is a reciprocal device.

The invention is based on the realisation that in a dual polarised phased array antenna, the relative positioning accuracy of the beams of different polarisation is not significantly reduced when the phase centres relating to one direction of polarisation are displaced transversely relative to the phase centres relating to the other polarisation direction by a distance equal to about half the matrix element spacing, and that by such a displacement of the antenna elements and their associated feeders relative to intersections of interengaging insulating planar supports which form a corresponding matrix support structure for the antenna, it is possible to avoid undesirable restrictions and compromises in respect of circuit interconnections and feeder connections resulting from the presence of the interengagement slots located on the respective axes of some of the antenna elements when these are formed as printed circuit type conductive patterns on the insulating planar supports.

An embodiment of the invention will now be described, by way of example, with reference to Figures 2,3 and 4 of the accompanying drawings, of which:-

Figure 2 is a perspective diagram illustrating a portion of a dual polarised phased array antenna in accordance with the invention,

Figure 3a and 3b respectively illustrate diagrammatically the horizontal and vertical printed circuit boards employed to form the structure of Figure 2, and

Figure 4 is a diagram illustrating one method of feeding an antenna element employed in the antenna of Figure 2.

Figure 2 illustrates diagrammatically and in perspective, a portion of a dual polarised phased array antenna in accordance with the invention in which a support structure 10 comprises an assembly of two orthogonal sets of parallel insulating planar supports, formed in the present example by horizontal and vertical dielectric plates 11, 12, respectively, the planar supports of one set intersecting and interengaging the planar supports of the other set so as to provide the support structure 10 of matrix form. This interengagement is effected by providing each of the planar supports 11,12, at the respective points of intersection with the planar supports 12,11, of the other set, with a cooperating discontinuity in the form of a slot 14 formed, in the present example, to half way across the support from front to back.

Each of the insulating planar supports 11,12, of each set is provided with a patterned conductive surface layer 15 which includes a succession of antenna elements 17 distributed along a corresponding outward facing edge of the planar support

11,12, which faces in the general direction to which or from which electromagnetic radiation is to be projected or received by the antenna structure 10. In the present example each antenna element 17 is in the form of an end-fire tapered slot antenna comprising a slot in the planar conducting surface layer 15 and each slot has an exponential taper from the throat 18 (Figure 4) to the open end 22 of the tapered slot antenna element 17. This form of antenna is sometimes called a Vivaldi antenna and is described in United Kingdom Patent Number GB 1,601,441. The description of a Vivaldi antenna is hereby assumed to be incorporated herein by way of reference and for this reason the antenna element will not be further described in detail herein. The throat or narrow end 18 of the slot is connected to an open circuit loop 19 and is connected to a feeder 20 which can be a strip line or the central conductor of a triplate line when, in the latter case, the patterned conductive surface layer 15 is repeated on the other major surface of a layered dielectric sheet 11. A connecting pillar 21 connects the end of the line 20 to the conductive surface layer 15 forming the ground plane of the feeder, on the far side of the throat 18.

The Vivaldi antenna element provides an electrical polarisation direction which is coplanar with the plane of the dielectric plate on which it is formed. Thus the parallel assembly of the vertical planar supports 12 each with a linear array of Vivaldi elements 17 forms a matrix array of antenna elements with a vertical direction of polarisation and the parallel assembly of the horizontal planar supports 11 forms a corresponding matrix array of antenna elements with a horizontal direction of polarisation.

A conventional dual polarised phase array antenna, as illustrated for example in Figure 1a, is arranged so that the phase centres of the corresponding vertically and horizontally polarised elements of the array are coincident.

In the antenna of Figure 2, however, the phase centres 16 of those antenna elements 17 on the planar supports 11 forming the matrix array relating to one polarisation direction (horizontal), are offset from the phase centres 16 of corresponding antenna elements 17 on the planar supports 12 forming the matrix array relating to the other polarisation direction. In the embodiment shown in Figure 2, the respective phase centre 16 of each of the antenna elements 17, is located on the corresponding planar support 11,12, between successive points of intersection therewith of planar supports 12,11, orthogonal thereto, which correspond to the locations of the slots 14, and in the present example the elements 17 are located midway between successive slots 14. This step is based on the realisation that the transverse offset displacement of the phase centres of the matrix array relating to one direction of polarisation relative to the corresponding phase centres of the matrix array relating to the other polarisation direction by a distance of about one half of the interelement spacing of either matrix, will only affect the accuracy of coordinating and tracking the directions of the respective orthogonally polarised beams to a negligible extent. As a result of this displacement of the antenna elements from the plate intersections, the dual polarised phased antenna array can be constructed entirely from printed circuit boards which are then simply slotted together to form the matrix antenna structure 10. Each of the circuit boards 11,12, can include conventional amplifying, modulating, switching, phase shifting and timing means (not shown) associated with the individual antenna elements 17 of the linear array formed thereby in order to perform the function of a phased array. External electrical connections can readily be provided to each board 11,12, via printed circuit cable connectors attached to the rear edge of the board, and connected to conventional circuitry for further phasing the corresponding parallel assembled linear arrays forming the associated matrix for reception and/or transmission of signals in three dimensions and having the corresponding polarisation direction. The plates 11 and 12 can be formed from conventional microstrip or triplate boards.

The plates 11,12, can be moulded or they can be formed from sheet dielectric material by stamping, cutting or milling. A suitable sheet dielectric is glass fibre reinforced PTFE. The conductive surface pattern can be formed by a printed circuit technique from copper cladding applied to the surface of the plates 11,12. Another suitable dielectric is alumina and the conductive surface pattern can be formed by a thick film technique or by vapour deposition of nichrome-gold or aluminium via a mask. Other suitable dielectric support materials are quartz, titanium dioxide, gallium arsenide or high-purity silicon.

Although Figure 2 shows only part of the antenna array embodying the invention, the remainder of the antenna will be substantially identical in construction to that shown in Figure 2, and in one example each component polarised array comprised a matrix of 8 x 8 antenna elements. In practice, a dual polarised phased array antenna having a larger number of antenna elements can readily be constructed in accordance with the invention.

The invention is not limited to the use of tapered slot antenna elements, and if elements having a wider beamwidth were required, tapered notch elements similar to those described in the previously mentioned paper by Lewis et al., can be employed. The advantages of the invention can

also be realised when employing other forms of end-fire printed circuit antenna elements such as a dipole element or an end-fire array of dipole elements, for example a Yagi array.

Claims

1. A dual polarised phased array antenna comprising two corresponding matrix arrays of antenna elements respectively providing orthogonal directions of polarisation, mounted on a support structure and energised by associated feeder means so as to form a phased antenna array of corresponding polarisation, said support structure comprising an assembly of two orthogonal sets of parallel illustrating planar supports, the supports of one set intersecting and interengaging the supports of the other set to form a support structure of matrix form, the insulating planar supports of each set each being provided with a conductive surface pattern including a succession of said antenna elements distributed along a corresponding outward facing edge of the planar support, characterised in that the phase centres of those antenna elements forming the matrix array relating to one polarisation direction, are offset from the phase centres of corresponding antenna elements forming the other matrix array.

2. An antenna as claimed in Claim 1, characterised in that the respective phase centre of each of said antenna elements is located on the corresponding planar support between successive intersections therewith of planar supports orthogonal thereto.

3. An antenna as claimed in Claim 1 or Claim 2, characterised in that each said antenna element comprises a tapered slot antenna element formed on the associated insulating planar support.

4. An antenna as claimed in Claim 3, characterised in that the respective longitudinal slot forming each tapered slot antenna element is provided with a substantially exponential taper.

5. An antenna as claimed in any one of Claims 1 to 4, characterised in that the insulating planar supports are formed from sheet dielectric.

6. An antenna as claimed in any one of Claims 1 to 5, characterised in that the insulating planar supports are formed from a polyolefin.

7. An antenna as claimed in any one of Claims 1 to 5, characterised in that said sheet dielectric is glass fibre reinforced PTFE.

8. An antenna as claimed in any one of Claims 1 to 7, characterised in that the conductive surface pattern is formed from copper cladding applied to the insulating planar supports, by means of a printed circuit technique.

9. An antenna as claimed in any one of Claims 1 to 4, characterised in that the insulating planar supports are formed of alumina.

10. An antenna as claimed in any one of Claims 1 to 4, characterised in that the insulating planar supports are formed of quartz.

11. An antenna as claimed in any one of Claims 1 to 10, characterised in that the conductive surface pattern is formed by a thick film process.

12. An antenna as claimed in Claim 9 or Claim 10, characterised in that the conductive surface pattern is formed by vapour deposition.

Fig.1a.

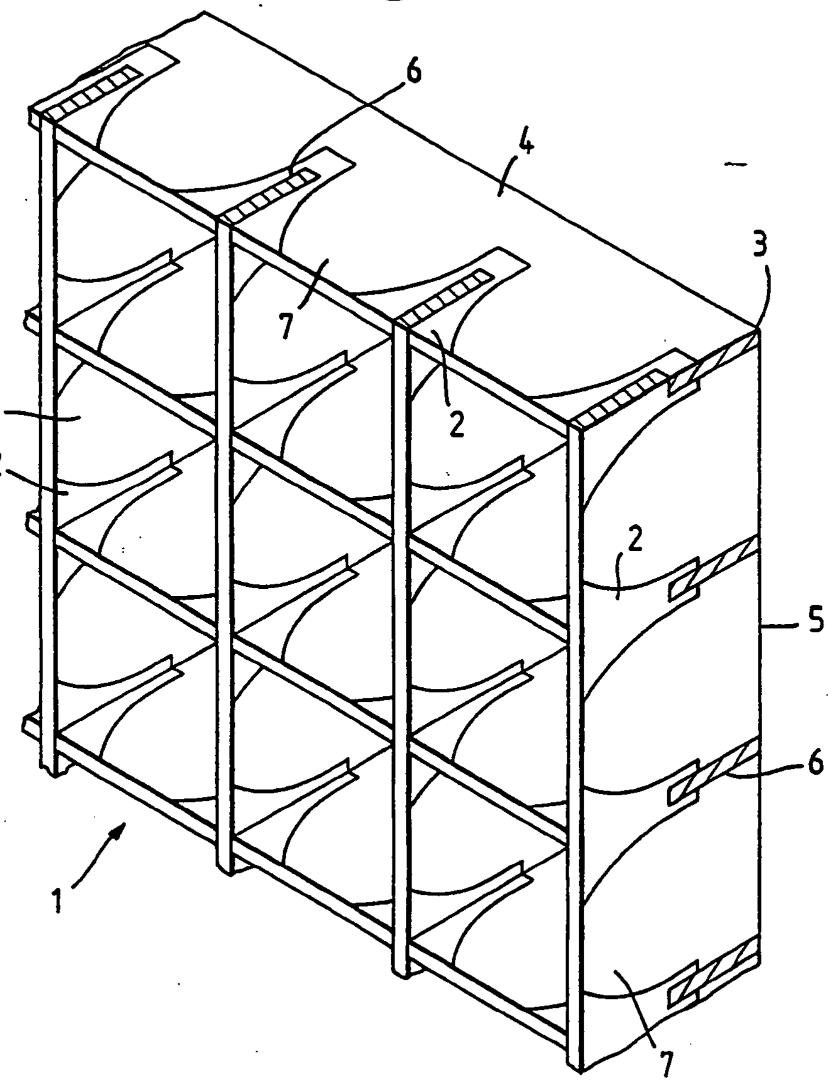


Fig.1b.

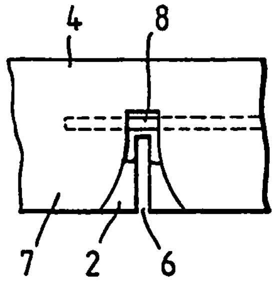


Fig.1c.

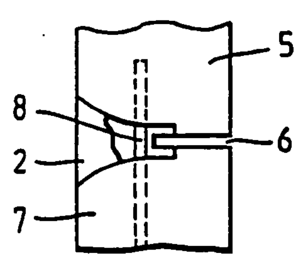


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Fig. 2.

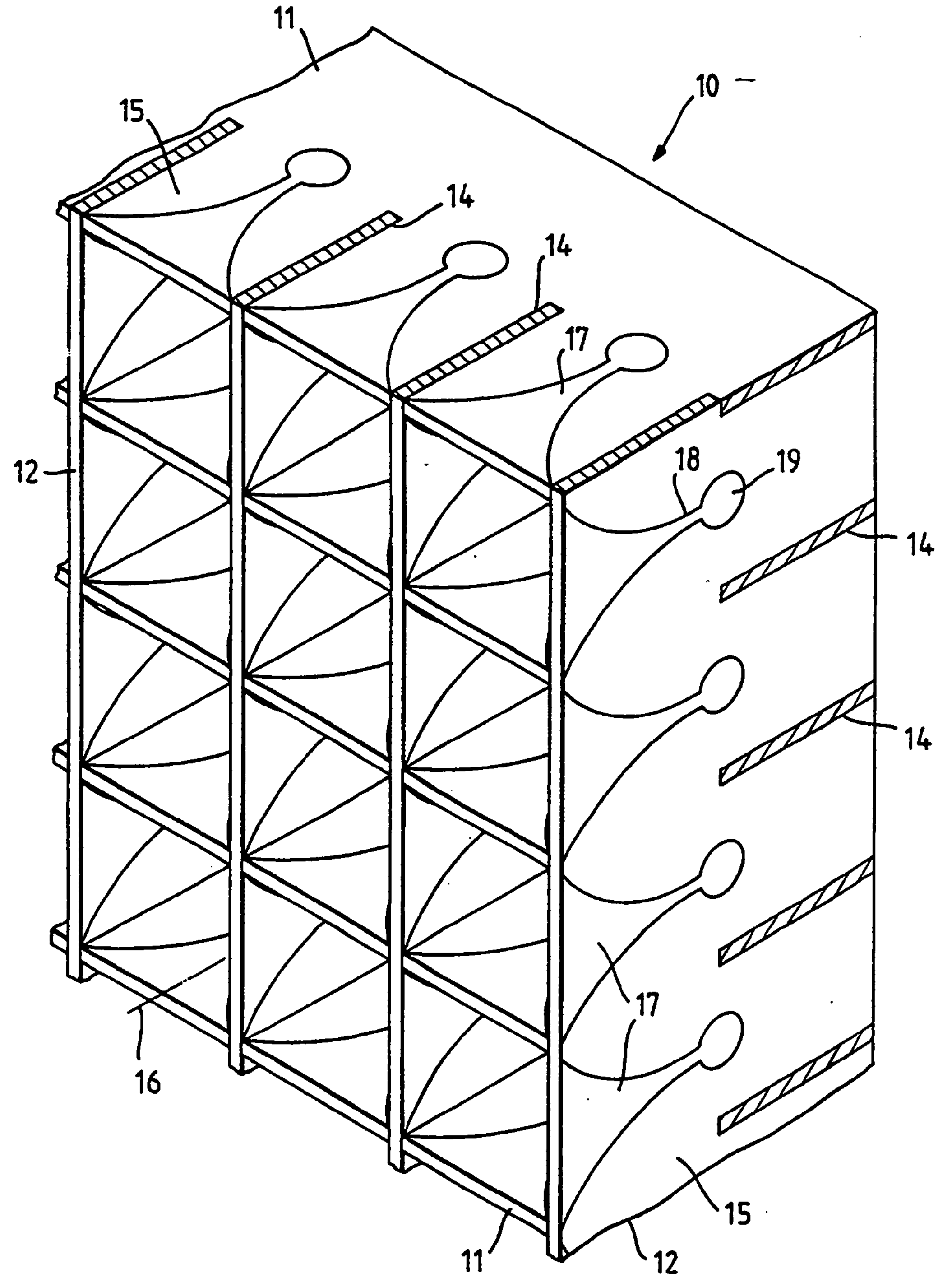

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Fig.3a.

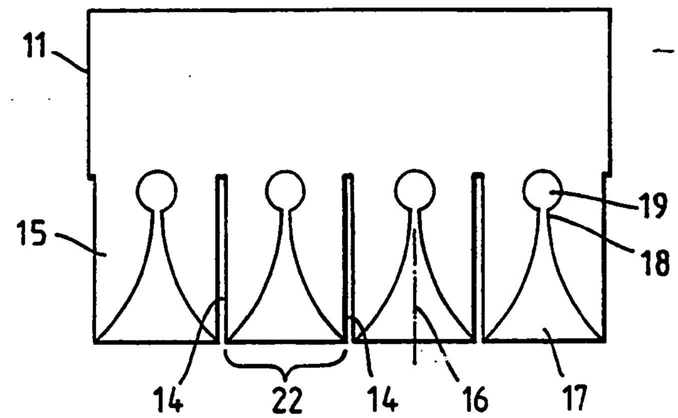


Fig.3b.

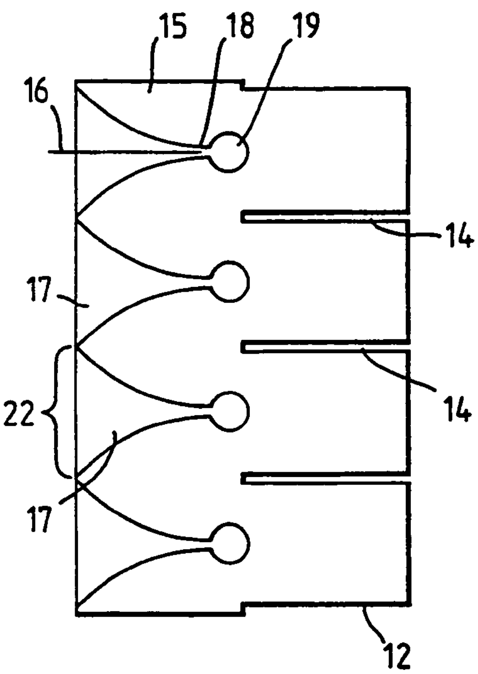
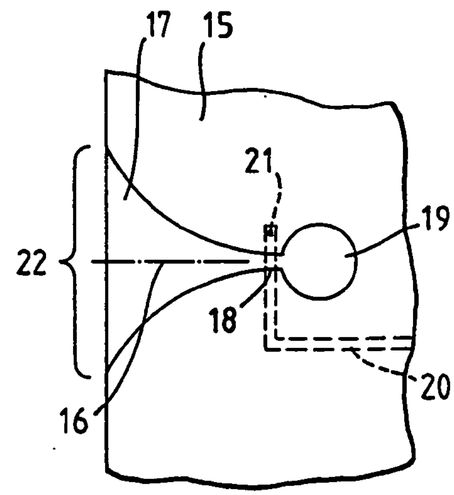


Fig.4.



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EUROPEAN SEARCH REPORT

Application Number

EP 89 20 1657

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	AP-S INTERNATIONAL SYMPOSIUM, Syracuse, 6th-10th June 1988, vol. 1, pages 200-203, IEEE, New York, US; M.J. POVINELLI et al.: "Design and performance of wideband dual polarized stripline notch arrays" * Whole document *	1-5,7,8,11,12	H 01 Q 25/00 H 01 Q 13/08
X	DE-A-3 334 844 (GENERAL ELECTRIC) * Figures 1,2,5; page 7, line 6 - page 8, line 8; page 9, line 1 - page 10, line 1; page 13, lines 12-21 *	1-5,7-9,11,12	
A	US-A-4 001 834 (T.M. SMITH)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H 01 Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06-09-1989	CHAIX DE LAVARENE C.P.H.

CATEGORY OF CITED DOCUMENTS

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